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Effect of KOH Concentration on LEO Cycle Life of IPV Nickel-Hydrogen Flight Cells—An Update

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NICKEL-HYDROGEN FLIGHT CELLS. AN UPDATE
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EXPERIMENTAL

Test Facility

The facility is capable of testing 45 battery packs with maximum of 10 cells electrically connected in series per pack. Each pack has its own charge and discharge power supply controlled by a computer which is programmed to satisfy the particular test requirements. During testing each pack is scanned every 2.4 min to compare data such as voltage, temperature and pressure with programmed limits. If a parameter is out of limit an alarm will be initiated and a message will be typed out identifying the cell and parameter. The data is recorded on a 132 mB disc drive and if requested can be obtained in report form. The cell temperature during a test is controlled by a recirculating cooler that circulates a solution of water and ethylene glycol through a cooling plate.

Cell Description

Six Air Force/Hughes recirculation design IPV nickel-hydrogen flight cells manufactured by Hughes are undergoing testing. Three of the cells contain 26 percent KOH electrolyte (test cells). The other three (control cells) are identical to the test cells except they contain 31 percent KOH. Both the test and control cells contain an equal number of components. The name plate capacity is 48 Ahr. The cell is illustrated in figure 1. It consists of a stack of nickel electrodes, separators, hydrogen electrodes, and a gas screen assembled in a non-back-to-back electrode configuration. In this configuration electrodes of different types directly face each other. The stack is packaged in a cylindrical pressure vessel, with hemispherical end caps. This is made of Inconel 718 and lined with zirconium dioxide which serves as a wall wick. The components are shaped in a pineapple slice pattern. The electrodes are connected electrically in parallel. The separators consist of two layers of zircar, which extend beyond the electrodes to contact the wall wick. Hence, the electrolyte which leaves the stack during cycling will be wicked back. The gas screens are polypropylene. The nickel electrode consists of a dry sinter plaque containing a nickel screen substrate which was electrochemically impregnated by the alcoholic Pickett process [5].

Measurements and Procedure

For the experiment the quantities measured every 2.4 min for each cell during charge and discharge and their accuracies are: current (± 2.0 percent), voltage (± 0.001 percent), pressure (± 1 percent), and temperature

(± 1 percent). Charge and discharge ampere-hour capacities are calculated from current and time. Charge to discharge ratio (ampere-hours into cell on charge to ampere-hours out on discharge) is calculated from the capacities. Cell charge and discharge currents are calculated from the voltage measured across a shunt, using an integrating digital voltmeter. Cell pressure is measured using a strain gauge located on the cell dome. The temperature was measured using a thermistor located on the center of the pressure vessel dome. The thermistor is mounted using a heat sink compound to insure good thermal contact.

Prior to cell final hydrogen gas adjustment, the nickel electrodes were positively charged, which results in a 0 psia hydrogen gas pressure. After completion of acceptance testing the cells were discharged at the C/10 rate (4.8 A) to 0.1 V or less. The cells were shipped to NWSC, Crane, Indiana, where they were stored at 10 °C and trickle charged at C/200 for 31 days. After storage the discharge ampere-hour capacity acceptance test was repeated. The capacity was measured after charging the cells at the C/2 rate (24 A) for 2.0 hr, then C/10 for 6 hr, followed by a 0.5 hr open circuit stand. The discharge capacity was measured to 1.0 V at each of the following rates: C/2, C, 1.4 and 2 C.

Prior to undergoing cycle life testing the capacity retention after a 72 hr open circuit stand (10 °C) was measured for all cells. For the cycle life test the cells were connected electrically in series to form a six cell pack. The cycle regime was a 90 min LEO orbit consisting of a 54 min charge at a constant 0.93 C rate (44.7 A) followed by a 36 min discharge at a 1.33 C rate (64 A). The charge to discharge ratio was 1.048. The depth-of-discharge was 80 percent of name plate capacity (48 Ah). During the cycle life test the cooling plate temperature was maintained at 10 ± 2 °C. Cell failure for this test was defined to occur when the discharge voltage degrades to 1.0 V during the course of the 36 min discharge.

RESULTS AND DISCUSSION

Storage Test

The nickel-hydrogen battery could undergo a planned or unplanned storage due to delays prior to launch. What effect will this have on performance? The influence of storage (31 days, trickle charged at C/200, 10 °C) on the capacity of the 48 Ah IPV nickel-hydrogen flight cells containing 26 and 31 percent KOH electrolyte is shown in figure 2. The spread in the data indicate there is no

significant capacity loss after 31 days for either the 26 or 31 percent KOH cells.

Performance Test

A comparison of the average discharge voltage at 1.4C rate (3 cells) as a function of time for the cells containing 26 and 31 percent KOH was made and is shown in figure 3. The voltage for the 26 percent KOH cells is higher than for the 31 percent KOH cells up to about an 82 percent depth-of-discharge. The discharge rate was 1.4C (67.2A) and the cell temperature was maintained at 10 °C. The ampere hour capacity for these cells is shown in table I (1.4C, 10 °C). The capacity on the average for the 26 percent KOH cells was about 10 percent lower than the 31 percent KOH cells. This relatively small decrease in initial capacity is traded for a significant increase in cycle life. It should be noted that the data in table I is for a 100 percent DOD. In an actual application the DOD will be much less, for instance the DOD for Space Station Freedom will be about 35 percent. At this DOD the portion of the curve in figure 3 being operated at is where the cells containing 26 percent KOH have a higher discharge voltage, and still have adequate capacity reserve.

Cycle Test

The influence of LEO cycling at 80 percent DOD on the end of discharge voltage for the 48 Ah IPV nickel-hydrogen flight cells containing 26 percent KOH is summarized in figure 4. After over 14 000 cycles there has been no cell failure. The influence of cycling on the end of charge pressure for the 26 percent KOH cells is shown in figure 5. The pressure increase on the average is about 36 percent at cycle 10 634. The pressure increase could be indicative of nickel plaque corrosion which converts nickel to active material. The increase in pressure will result in a shift in the beginning of life state-of-charge versus pressure curve.

The influence of LEO cycling at 80 percent DOD on the end of discharge voltage for the cells containing 31 percent KOH is shown in figure 6. All three cells failed (cycle 3 729, 4 165, and 11 355). The failure mode for each cell was characterized by degradation of discharge voltage to 1.0 V. No cell failed due to an electrical short. A comparison of the discharge curve at the beginning and end of life for cell 1, which failed at cycle 3 729 is shown in figure 7. This information also shows a voltage degradation. For this cell the ampere-hour capacity decrease was about 33 percent (1.4 C rate, 10 °C), for cell 2 it also was 33 percent and for cell 3 it was 36 percent. The influence of cycling on the end of

charge pressure for the 31 percent KOH cells is shown in figure 8. The pressure change can be correlated with the discharge voltage change due to cycling. The pressure increase for cell 3 at cycle 10 634 is 37 percent. The pressure increase is about the same as for the 26 percent KOH cells which on the average was 36 percent at this cycle. The three failed cells have undergone teardown and failure analysis at Hughes Aircraft under a NASA Lewis contract. The results of the DPA will be presented by Hong S. Lim of Hughes at the 1991 IECEC August 4-9, 1991.

The superior performance of the 26 percent KOH cells compared to the 31 percent cells is in agreement with boiler plate cell results reported previously [2,3]. It is attributed to a crystallographic change of active material [6]. Gamma NiOOH to beta in 26 percent KOH. Beta nickel hydroxide has a lower capacity but longer life.

CONCLUDING REMARKS

A breakthrough in the low-earth-orbit cycle life of individual pressure vessel nickel-hydrogen battery cells was reported. The cycle life of boiler plate cells containing 26 percent KOH electrolyte was about 40 000 accelerated LEO cycles at 80 percent DOD compared to 3 500 cycles for cells containing 31 percent KOH. Results of the boiler plate cell test are in the process of being validated at NWSC, Crane. Forty-eight ampere-hour flight cells containing 26 and 31 percent KOH are undergoing real time LEO cycle life testing at an 80 percent DOD, 10 °C. The three cells containing 26 percent KOH have been cycled for over 14 000 cycles with no cell failure. All three cells containing 31 percent KOH failed (cycle 3 729, 4 165, and 11 355). They have undergone teardown and failure analysis.

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TABLE I. - CAPACITY OF
HUGHES FLIGHT CELLS
CONTAINING 26 AND 31
PERCENT KOH ELECTROLYTE

Cell	Capacity, ^a A-hr	KOH concentration, percent
1	59.0	31
2	59.9	31
3	59.0	31
4	53.8	26
5	53.2	26
6	52.3	26

^aDischarge at 1.4C rate, 10 °C.

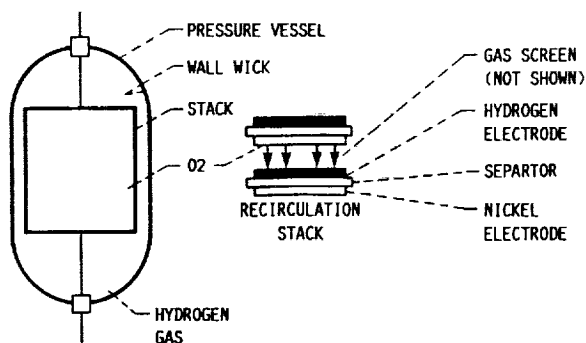


FIGURE 1. - ILLUSTRATION OF HUGHES RECIRCULATION STACK INDIVIDUAL PRESSURE VESSEL NICKEL-HYDROGEN CELL.

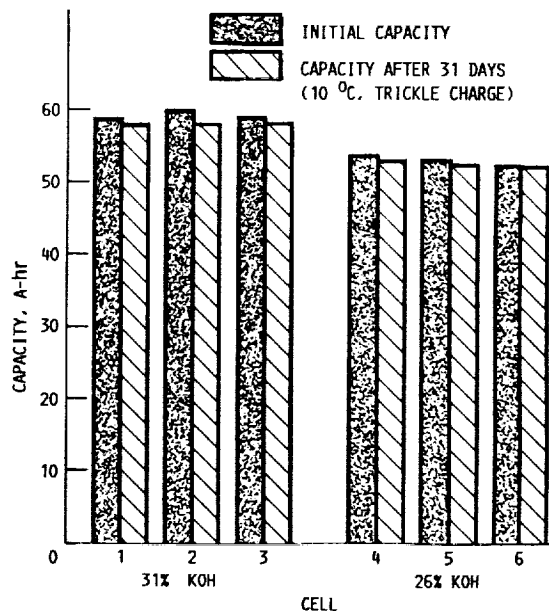


FIGURE 2. - EFFECT OF STORAGE ON CAPACITY OF 48 A-hr HUGHES IPV NI/H₂ FLIGHT CELLS.

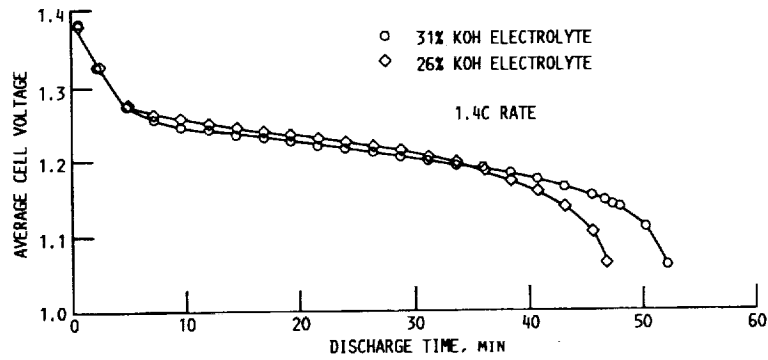


FIGURE 3. - COMPARISON OF HUGHES 48 A-hr IPV Ni/H_2 FLIGHT CELLS CONTAINING 26% AND 31% KOH ELECTROLYTE.

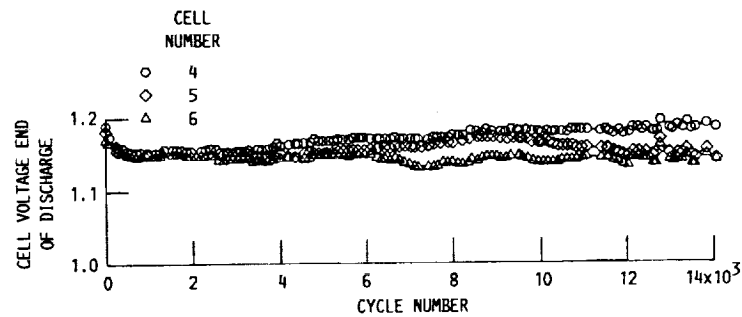


FIGURE 4. - EFFECT OF LEO CYCLING AT 80 PERCENT DOD ON HUGHES FLIGHT CELLS CONTAINING 26 PERCENT KOH ELECTROLYTE, 10°C .

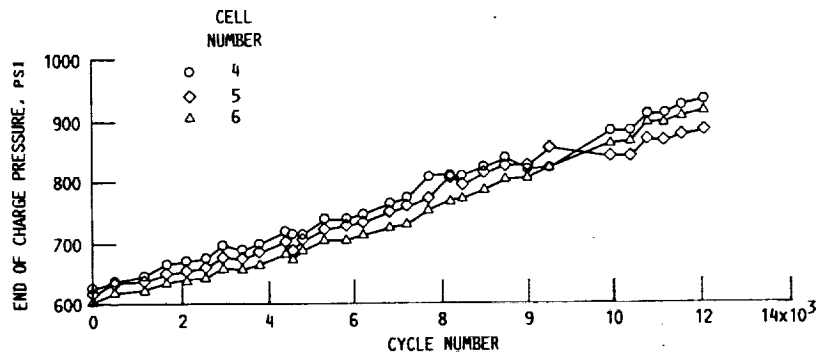


FIGURE 5. - EFFECT OF LEO CYCLING AT 80 PERCENT DOD ON HUGHES FLIGHT CELLS CONTAINING 26 PERCENT KOH.

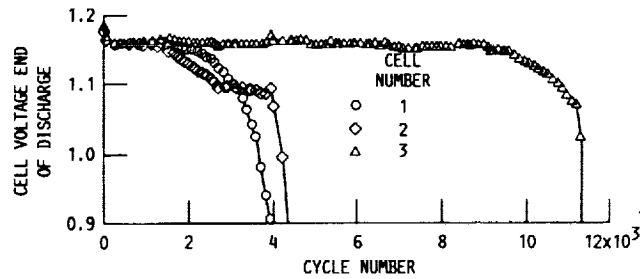


FIGURE 6. - EFFECT OF LEO CYCLING AT 80 PERCENT DOD ON HUGHES FLIGHT CELLS CONTAINING 31 PERCENT KOH ELECTROLYTE, 10 °C.

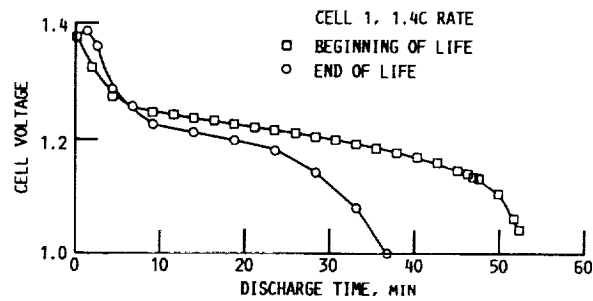


FIGURE 7. - CELL VOLTAGE FOR HUGHES 48 A-hr IPV Ni/H₂ FLIGHT CELL CONTAINING 31 PERCENT KOH ELECTROLYTE.

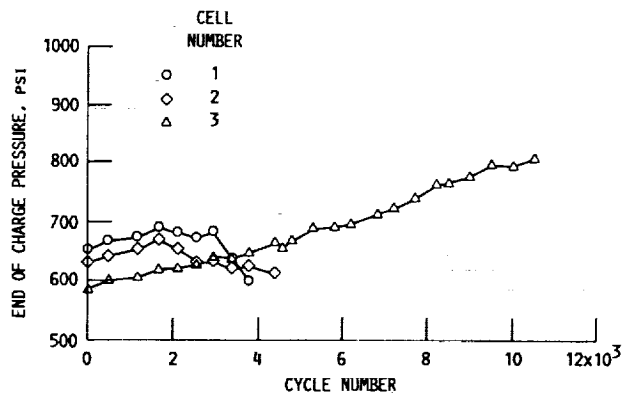


FIGURE 8. - EFFECT OF LEO CYCLING AT 80 PERCENT DOD ON HUGHES FLIGHT CELLS CONTAINING 31 PERCENT KOH.



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16. Abstract An update of validation test results confirming the breakthrough in LEO cycle life of nickel-hydrogen cells containing 26 percent KOH electrolyte is presented. A breakthrough in the low-earth-orbit (LEO) cycle life of individual pressure vessel (IPV) nickel-hydrogen cells was reported. The cycle life of boiler plate cells containing 26 percent potassium hydroxide (KOH) electrolyte was about 40,000 LEO cycles compared to 3500 cycles for cells containing 31 percent KOH. This test was conducted at Hughes under a NASA Lewis contract. The purpose for the contract was to investigate effect of KOH concentration on cycle life. The cycle regime was a stressful accelerated LEO, which consisted of 27.5 minute charge followed by 17.5 minute discharge (2x normal rate). The depth of discharge (DOD) was 80 percent. The cell temperature was maintained at 23 °C. The boiler plate test results are in the process of being validated using flight hardware and real time LEO test at the Naval Weapons Support Center (NWSC), Crane, Indiana under a NASA Lewis Contract. Six 48 Ah Hughes recirculation design IPV nickel-hydrogen flight battery cells are being evaluated. Three of the cells contain 26 percent KOH (test cells), and three contain 31 percent KOH (control cells). They are undergoing real time LEO cycle life testing. The cycle regime is a 90-minute LEO orbit consisting of a 54-minute charge followed by a 36-minute discharge. The depth-of-discharge is 80 percent. The cell temperature is maintained at 10 °C. The 26 percent KOH cells have been cycled for over 14,000 cycles with no cell failure in the continuing test. However, all three 31 percent KOH cells failed (cycles 3729, 4165 and 11355).					
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